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EVALUATION OF VIBRIOSIS VACCINATION IMPACT ON MARINE FISH USING PARTIAL BUDGET MODEL FRAMEWORK

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CONTENT

LIST OF FIGURES

LIST OF TABLES

PENILAIAN KESAN VAKSINASI VIBRIOSIS PADA IKAN LAUT MENGGUNAKAN KERANGKA MODEL BAJET

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Abstrak

Pelbagai penyakit yang dihadapai oleh ikan marin boleh menyebabkan kerugian dalam industry akuakultur, terutamanya melibatkan jangkitan oleh bakteria. *Vibrio spp.* adalah salah satu jenis bakteria yang boleh menyebabkan wabak di kalangan ikan marin di dunia yang boleh menyebabkan kerugian ekonomi yang besar. Wabak ini lazimnya dikaitkan dengan kedua-dua ikan laut liar dan ternakan, dan ia dianggap sebagai masalah utama dalam industri akuakultur di seluruh dunia, mengakibatkan kerugian kewangan yang ketara. Disebabkan ini, kajian ini dijalankan dengan dua objektif utama iaitu untuk menilai kesan ekonomi vaksinasi vibriosis ke atas ikan laut dan untuk membangunkan rangka kerja bajet separa untuk menilai kesan ekonomi vaksinasi vibriosis ke atas ikan laut. Beberapa vaksin terhadap vibriosis telah dibangunkan, termasuk vaksin DNA, vaksin yang dilemahkan hidup, dan vaksin yang tidak aktif, serta vaksin yang mengandungi patogen bakteria yang tidak aktif untuk mencegah wabak vibriosis. Sebaliknya, belanjawan separa ialah rangka kerja perancangan dan membuat keputusan untuk perniagaan ladang untuk membandingkan kos dan faedah pelbagai pilihan yang memberi tumpuan semata-mata kepada perubahan dalam pendapatan dan perbelanjaan yang akan berlaku jika alternatif tertentu dilaksanakan. 4 komponen membentuk model belanjawan separa iaitu pendapatan tambahan, kos tambahan, kos berkurangan dan pendapatan berkurangan. Dalam kajian ini, model bajet separa akan digunakan untuk membuat keputusan tentang vaksinasi vibriosis untuk ikan laut yang akan menyumbang kepada pengurangan kerugian akibat vibriosis dan memaksimumkan keuntungan dan potensi keuntungan.

Kata kunci: Vibrio spp.; ikan laut; kesan ekonomi; vaksinasi; rangka kerja belanjawan separa

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Abstract

Multiple diseases of marine fish can lead to economic losses in mariculture, especially when they are caused by bacteria. *Vibrio spp.* is one the main bacteria that caused outbreaks in marine fish worldwide which leads to great economical loss. It is commonly associated with both wild and farmed marine fish, and it is considered as a major problem in the aquaculture industry around the world, resulting in significant financial losses. Due to this, the study was conducted with two major objectives which is to assess the economic impact of vibriosis vaccination on marine fish and to develop a partial budget framework to evaluate the economic impacts of vibriosis vaccination on marine fish. Several vaccines against vibriosis have been developed, including DNA vaccines, live attenuated vaccines, and inactivated vaccines, as well as vaccines that contain inactivated bacterial pathogens to prevent vibriosis outbreak. On the other hand, partial budget is a planning and decision-making framework for a farm business to compare the costs and benefits of various options which focuses solely on the changes in income and expenses that would occur if a specific alternative were implemented. 4 component makes up partial budget model which are added income, added cost, reduced cost and reduced income. In this study, partial budget model will be used to make decisions about vibriosis vaccination for marine fish which will contribute to reducing loss due to vibriosis and maximizing profits and profit potential.

Keywords: ***Vibrio spp.;*** **marine fish; economic impact; vaccination; partial budget framework**

INTRODUCTION

Aquaculture in the sea is a fast expanding sector that poses both opportunities and threats to the environment and society (Davies et al., 2019). In 2008, global aquaculture reached 52,5 million tons which produces in income US$106 (RM442.95) billion in income, including aquatic plants) and provided half of the world's fish food. In 2007, aquaculture contributed 43.3% of aquatic animal food consumed by humans (i.e., fish, crustaceans, mollusks, but excluding mammals, reptiles, and aquatic plants), and it is expected to grow further in the future. Globalization of trade and favorable economics of bigger scale intensive farming have fueled fast expansion in the production of carnivorous species such as salmon, shrimp, and catfish (Bostock et al., 2010). In addition, (Hishamunda et al., 2009) stated that aquaculture is a source of protein, employment, income, and foreign exchange for developing countries, which produce 90% of the world's output. Southeast Asia becomes the main producers of aquaculture as it undergoes "blue revolution" which contributes to quarter of fish food supply globally in which the region's total aquaculture output surged from about two million tons in 1990 to over eight million tons in 2006.

However, there are a variety of concerns to marine aquaculture that contribute to a substantial loss of economic value, particularly because of climate change, government policy changes, and disease outbreaks due to bacteria or viruses. Over the last few decades, a variety of bacterial diseases, primarily caused by *Vibrio spp.* and Photobacterium spp., have been reported in marine cultured fish around the world, with mainly causing mortality accounted for Vibriosis. *Vibrio spp.* infection caused high mortality at the nursery stage, with ocular lesions, pale liver, ulcers at the caudal peduncle and tail, and aberrant swimming behavior (Abdullah & Ridzuan, 2017). Gram-negative bacteria, *Vibrio spp.* possess polar flagella enclosed within a sheath and are rod-like or comma-shaped (Mohamad et al., 2019a) causing severe economic losses and is responsible for massive mortality in cultured shrimp, fish, and shellfish (Novriadi, 2016).

Early intervention, such as immunization, can, nevertheless, be utilized to prevent and decrease Vibrio spp. outbreaks. Vaccination has been shown in numerous trials to reduce mortality and enhance survival rates in fish with Vibriosis. For example, studies by (Nguyen et al., 2017) observed a high relative percentage survival values of 100% and 91.7% after 6 weeks and 12 weeks post vaccination using vibrio vaccine against homologous *V. harveyi* strain. Even though vaccination contributes to a reduction of mortality rates, which results in economic losses, the procedure also added cost in the operating costs.

Partial budgeting however contributes towards the best outcome related in determining if vaccination for the prevention of Vibriosis in marine fish is worthwhile. The partial budget helps agricultural owners/managers assess how incremental changes will affect their financial situation and it is also made up from four components which is added income, added cost, reduced cost and reduced returns (Tigner, 2018). Yet, In Malaysia, little research has been done using a partial budget model framework to examine the impact of vibriosis vaccination on marine fish. There is still a scarcity of comprehensive information on actual calculation on profit made if vibriosis vaccination implemented in marine aquaculture compared to loss farmer would face if outbreak occurred in unvaccinated fishes.

As a result, an assessment of the implementation of a partial budget framework for fish vaccination against vibriosis is critical to gain a better understanding of the benefits of the vaccine in marine aquaculture. The primary objective of this narrative review is to evaluate the economic impact of vibriosis vaccination in marine fish in cage culture and to develop a partial budget framework for assessing the economic impact of vibriosis vaccination on marine fish in terms of treatment costs and mortality rates.

MATERIALS AND METHOD

Materials

Google Scholar, Scopus and Science Direct database being used from 2000 until 2021 by using these following keywords: marine fish: fish vaccine: Southeast Asia: cost: economic: mortality and combination of these terms. All the articles that have been retrieved in their full extent had their reference lists searched too. Tittle and abstract of the article found were reviewed. A review of the full texts of potentially relevant papers is done, as well as a search of their reference lists. Research and report regarding fish vaccination especially Vibriosis vaccination and its economic impact towards marine fish production is the criteria used to search for the papers. To make this narrative review, information from the selected articles was summarized and incorporated into each section. In total, 74 papers have been reviewed based on its information regarding fish disease in marine animals, Vibriosis impact on marine aquaculture, benefit of implementing Vibrios vaccination, the use of partial budget model in farming system in term of loss and profits estimated and finally the implantation of partial budget on fish vaccination.

Method

Partial budget framework:

Status quo

Change in farm health management

Benefits	**Costs Benefits**
A. Additional income (Returns received because of growing a new practice or commodity)	**D. Additional Cost** (Cost included results of growing/using/implementing new practices)
B. Reduced cost (Cost that will not be incurred because of giving up current practice/commodity for a new one)	**E. Reduced income** (Returns that are given up because of no longer producing the current commodity
C. Total benefit (A+B)	**F. Total cost (D+E)**
Net change in profit (C – F)	

Table 1: Partial budget component; Added income, added cost, reduced cost as well as reduced income

Partial budgeting is a tool used to assess the costs and benefits associated with a specific change within the operating structure of a business. It consists of 4 components which are stated on Table 1; Added income, added cost, reduced cost as well as reduced income. In the partial budget model, the cost section has both added costs and reduced income. Both are the negative results of the proposed change while reduced costs and added income would be included in the benefits section of the partial budget and they are positive impacts of a proposed changes. A positive net benefit will result from the change if the benefits are greater than the costs. Changes should not be proposed if, in addition to the costs, the benefits are negative valued net benefits, since it will cost more to implement than it will yield, and therefore be rejected. Exchange of currency used in based on the latest currency worldwide (8/10/2021); 1US$ = RM 4.18, 1Tk = RM0.049, 1NOK = RM 0.49, 1£ = RM 5.68, 1LE = RM 0.27.

REVIEW BODY

AQUACULTURE PRODUCTION IN MALAYSIA

Since the world's population is on the rise, the demand for animal-based food has increased rapidly in recent decades, resulting in rapid growth of the aquaculture industry (See et al., 2021). On the basis of observed regional trends , the global aquaculture sector's fish supply will grow to 93.6 million tons in 2030 based on observed regional trends in seafood production and consumption, and using a global, partial equilibrium, multi-market scenario (Nadarajah & Flaaten, 2017). The increase in aquaculture activity were being led by factor such as urbanization as the urbanization of the market has also contributed to the rise of aquaculture demand since people living in cities are likely to put more money toward fish and eat out more often, thus contributing to increasing fish consumption (Ahmad et al., 2021). Over the past 50 years, aquaculture has grown dramatically to reach around 52,5 million tonnes in 2008 (68,3 million including aquatic plants) worth US$98.5 billion (RM412.07 billion) (US106 billion (RM443.45

billion) including aquatic plants) and supplying about half of the world's fish feed with this product dominated by Asia, accounting for 89% by volume and 79% by value, with China by far being the major producer (32,7 million tons in 2008) (Bostock et al., 2010). Today, 394, 580 tonnes of finfish production valued at over US$ 512 million (RM2141.95 million), with China being the largest producer (Kongkeo et al., 2010). In China, over one million traditional (mostly wooden) cages still account for most marine cages along coastal areas, such as Fujian (54%), Guangdong (15%), Zhejiang (10%), Shandong (7%), Hainan (5%) and other provinces (9%) as more than 65 species are being cultured in China's vast marine area, which includes both temperate and subtropical waters (Kongkeo et al., 2010). In order to achieve socioeconomic development, the fishery and aquaculture sectors play a an important role (Nadarajah & Flaaten, 2017). Aquaculture production and production from capture fisheries together accounted for almost three times the total output in the region between 1980 and 2006.

Four countries (China, Indonesia, Thailand, and Viet Nam) have seen significant increases in their marine finfish production over the years (Kongkeo et al., 2010). In Indonesia, fish cage culture is practiced in a large number of areas because there are many well-sheltered bays and the water quality is generally good compared to other Asian countries (Hishamunda et al., 2009). (Tran et al., 2017) also stated that In Indonesia, aquaculture is conducted in fresh, brackish, and marine waters, with production limited to a smaller number of fish species compared to capture fisheries. Thailand practices marine fish farming in the coastal areas of the Gulf of Thailand and its west as it has a larger potential for future growth due to improved water quality and water exchange, although there are fewer sheltered spots. Khan Hao and nearby provinces in central and southern Vietnam, there were over 40,000 cages that primarily farmed lobster but also produced marine fish, totalling over 1,000 tonnes (Kongkeo et al., 2010).

There is potential for Malaysia to become one of the most important fishing nations in Southeast Asia, and it is poised to add value to the marine fishing industry in a new era. This is evidenced by the fact that Malaysia's yearly total marine landings have increased, that Malaysia's offshore resources have considerable potential for further development (Saharuddin, 1995). Over the years, Malaysia's demand for fishery resources has steadily increased. Hence, to fulfil the demands, the government have implemented various plans and targets to increased fish production for consumption. For instance, the government's Ninth Malaysia Plan (RMK9) predicted that fisheries production would increase by 33.4%, or 1.8 million metric tonnes, and by 2010 Malaysia will achieve 103 percent self-sufficiency levels (Teh, 2012). Malaysia also acts as a source of foreign exchange, the export of fish and fish products generated M$739.7 million in 1991, accounting for about 0.8 percent of the total value of the country's exports. Fresh and frozen fish with a high market value, as well as crustaceans, are the main export commodities (mainly prawns and shrimps). Frozen crustaceans worth M$ 272 million, or about 37% of the total, are the main products exported to Japan, Singapore, and the United States (Saharuddin, 1995).

In Malaysia, seaweed aquaculture produced 174,083 tons of wet weight worth RM52 million. There were 325,328,503 ornamental fish produced in 2019, valued at RM350,326, while 117,006 bundles of aquatic plants were produced, valued at RM19,924. In 2004, as reported by the Ministry of Agriculture Malaysia, the fish consumption index increased by 1.6% from 49, 53, and 53.1 kg in 2000, 2005, and 2010, respectively, and is expected to reach 64 kg in 2020 which shows that as Malaysia's population has grown throughout the years, the demand for fishery resources has been sharply increasing as well. (Kurniawan et al., 2021). (Fisheries Development Authority of Malaysia, 2019) stated that in 2019, fish trade balance shows import statistic at about1,673,556 tonne metric worth at RM10.4 million while export value at 446,059 tonne metric worth at RM3.7 million. Export transaction calculated to be higher than the import transaction which is 69% compared to 31% in which most of this transaction occurred widely in Sabah and Sarawak. 5 species of fish become the most preferred by Malaysian due to its retails price which is torpedo scad (*Megalaspis cordyla*), mackerel (*Scomber scombrus*), Indian mackerel (*Rastrelliger kanagurta*), yellowtail scad (*Atule mate*) and mackerel scad (*Decapterus macarells*). From the 5 fish species listed, mackerel (*Scomber scombrus*) and, yellowtail scad (*Atule mate*) listed as the highest average price yearly at RM13.00/kg, followed by Indian mackerel (*Rastrelliger kanagurta*) at RM11.00/kg while mackerel scad (*Decapterus macarells*) and torpedo scad (*Megalaspis cordyla*) have the lowest price listed at RM10.00 dan RM9.00 per kilogram. Therefore, marine fish stock in 2019 is contributed from local supplies (42%), import (49%) and marine aquaculture (9%) amounted at 3,436,183 tonne metrics. Malaysia fish product reaches U$0.87 billion (RM3.63 billion) with the main exposed focuses on shrimp, squids, live fish, and ornamental fishes. Figure 1 shows Malaysia main export commodities in 2014 while Malaysia imported US$1.15 billion (RM4.79 billion) for fish food (Fazial.A,2017).

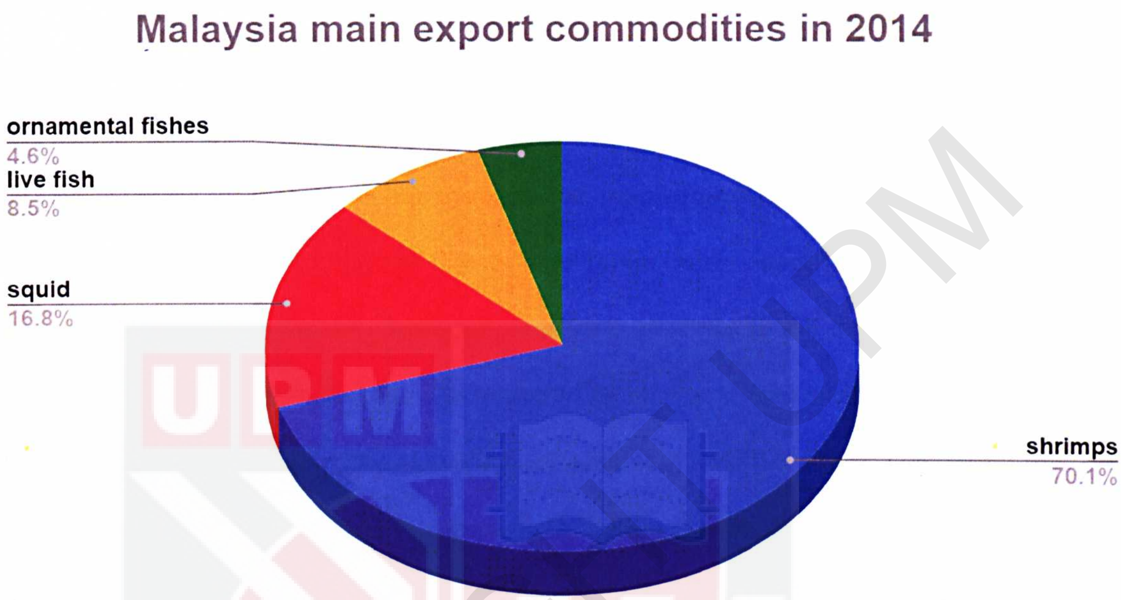

Figure 1. Malaysia main export commodities in 2014

COMMON COMMON FISH SPECIES IN AQUACULTURE

Since the early 1980s, aquaculture has grown substantially in a few EU countries, and it is primarily a form of economic development in remote areas, where alternative employment sources are scarce. These statement can be supported by marine aquaculture activities that occur throughout region such as (Atlantic salmon in Scotland, Norway and Ireland, seabass and seabream (*Sparus aurata*) in the Mediterranean and mussel (*Mytilus edulis*) farming by line or raft in Ireland, Spain and France) (Hishamunda et al., 2009) . Different types of aquaculture systems have been practiced to maximize production, including freshwater ponds , fresh water cage, a coastal pond, cage farms along the coast, marine mollusks and aquatic plants with the leading intensively farmed marine fish is Atlantic salmon, followed by white leg and tiger shrimp, oysters, scallops and mussels; however, shrimp are not farmed extensively along the coast (Bostock et al., 2010).

Several species being reared in different farming system to fulfill the demand for fish meat consumption in the Europe region as well in the Southeast region. However, different types of fish being reared according to the natural climate as different fishes adapt to different temperature and environment to survive. For example , there are tropical and subtropical environments throughout the Asia-Pacific region that support euryhaline species such as Asian sea bass or barramundi (*Lates calcarifer*) (Delamare-Deboutteville et al., 2006) . Despite being a relatively hardy species, the Asian seabass is capable of coping well with a wide range of physiological conditions other than having a high fecundity of females to provides lots of eggs for hatcheries. In addition, this species could also reach harvestable size around 350g to 5kg in a shorter period in a suitable environment accounted to its straightforward production method such as juvenile are simple to wean to pellet (Hua et al., 2009). The large domestic market and proximity to major seabass consumption centers in south-east Asian countries is an added benefit for easy export opportunities as Malaysia, Singapore, Hong Kong, Taiwan, Thailand, and the southern provinces of mainland China becoming an important seabass consumption centers, with seabass being preferred as a 600-700 g whole live table fish (Ravisankar & Thirunavukkarasu, 2010). Mouse or humpback grouper *(Cromileptes altivelis*), tiger grouper, Asian seabass (*Lates calcarifer*) are the examples of fish being widely cultured in Indonesia through cultured cages which is supported by the success in performing artificial hatcheries other than the usage of technologies in private hatchery operators such as in Lampung and Gondol (Bali) with more than 125 marine hatcheries operating (Kongkeo et al., 2010) . Following the development of CIBA's seabass production technology in 1977, a concerted effort has been made to popularize scientific seabass culture in India (Ravisankar & Thirunavukkarasu, 2010).

Other species are being widely reared in aquaculture is grouper especially in Thailand , Vietnam and Malaysia . (Kongkeo et al., 2010) also stated that in Vietnam, most of seed stock obtained from government and private hatcheries for cage culture species which is main species consist of orange- spotted grouper, tiger grouper, green or greasy grouper (*E. tauvina*), glass-eyed perch (*Psammopeca waigiensis*), seabream, cobia, red snapper, seabass, pompano, and red drum (*Scianops ocellatus*). Species of grouper being mostly reared in Vietnam includes *Epinephelus coioides* (Orange Spotted grouper), *E. fuscoguttatus* (Tiger grouper), *Plectropomusleopardus* (Coral trout), *E. lanceolatus* (Giant grouper) and in recent years *E. malabaricus* (Malabar grouper), *E. akaara* (Red-Spotted grouper) and *E. bleekeri* (Duskytail grouper). As new technology has been implemented in grouper farming in Vietnam , Hybrid grouper being produced by the cross breeding of *E. lanceolatus* X *E. fuscoguttatus* in which eggs from Tiger grouper being artificially mixed with milt from Giant Grouper (Dennis et al., 2020). By 2030, grouper production will be 79,000 t, nearly seven times higher than in 2012. (12,000 t) As a result, it is expected to have the highest proportionate growth which are expected to experienced three-fold increase up to 2030 followed by milkfish, shrimp and carps (Tran et al., 2017). This statement is also supported by (Kongkeo et al., 2010) which stated that United States, European Union, Singapore, Hong Kong, and China becoming countries that imported Mouse grouper fingerlings as it is popular in the marine ornamental trade.

Red Snapper come next to the most farmed marine fish in the Southeast region. Larger juveniles were collected at various times throughout the year (e.g., during May-June and October- November in Thua Thien Hue, and during February and September to December in Binh Dinh). According to the fishermen, approximately 1,700,000 juvenile fish (in Thua Thien Hue) and over 58,000 fish (in Binh Dinh) are caught each year at lagoons which connects to the river and mangrove forest where the salinity range from 10-25ppt (Chi & True, 2017) . Asian seabass, orange-spotted grouper, tiger grouper, areolate grouper (*E. areolatus*), Malabar grouper, dusky-tail grouper, coral trout, giant grouper, red snapper and cobia are examples of fish species that are being reared in Thailand (Kongkeo et al., 2010). Hence it is true as different types of fishes being utilized in aquaculture as it brings many benefits for country in term of food supply and consumption, increases country economics, protect coastline and aquatic environments. This is also true as Southeast Asia region per capita average fishing consumption rates across all seven countries are higher than world averages at 16.1 kilograms per person per year (Hishamunda et al., 2009). In term of economic, Viet Nam is the fourth ranked country in terms of finfish production, producing 2.7 million tons (5.4% of the global total), of which 92.2% were aquaculture (inland aquaculture), and 7.8% were seafood (FAO: Food and Agriculture Organization, 2016). As of 2015, fishery export earnings totaled US$6.5 billion (RM27.19 billion), up from less than US$500 million (RM 2091.75 million) at the time (Pomeroy et al., 2009; Van Dung et al., 2016).

COMMON AQUACULTURE DISEASES

The surrounding bacterial communities in water have a significant impact on the health of aquaculture fish and changes in the structure of a bacterial community can cause diseases in fish directly (Xue et al., 2017) . Fishes, unlike higher vertebrates, have a lower immune system, leading to major factor in their susceptibility for disease outbreaks. When a susceptible fish is exposed to a virulent pathogen in an unfavourable environment, a disease develops. A stressed fish population becomes vulnerable to a pathogen, either from the environment or from a carrier fish, and succumbs to infection (Harikrishnan & Balasundaram, 2005). Disease, floods, oxygen depletion, predation, chemical poisoning, theft, and other factors all contribute to losses for fish farmers. However, the most important factor is disease outbreak (Raja & Jithendran, 2015).

There are several factors that may led to disease in aquaculture system. Crowding, temperature fluctuations, insufficient dissolvable oxygen, excessive handling, physical abuse, inadequate diets, or toxic substances can all cause stress in animals (Wedemeyer et al., 1976). Most fish disease in aquaculture occurred due to stress which causes immune system of the fishes to be lowered, hence reducing the capability of the fish to fight against pathogen which in turn causes disease and produces clinical signs. Thus, most bacterial diseases of fish and shellfish are thought to be predisposed by "stress," and any situation that causes "stress" is likely to result in clinical disease (Raja & Jithendran, 2015) .

Disease may lead to economic losses due to high mortality of fishes in every stage from fingerlings to adults and due to increase cost and expenditures for the treatment of the disease. For example, it was estimated that $10 million (RM41.83 million) worth of catfish sales were lost due to disease and costs accounted for the treatment includes cost of medicated feed ($1.9 million(RM7.95 million)), chemical applications ($0.6 million (RM2.51 million)), and miscellaneous ($0.1 million(RM0.42 million)) are among the expenses that have been increased to manage and control diseases (Peterman & Posadas, 2019). Disease in marine fish have been associated with different types of pathogens ranging from bacteria, viruses, and parasite with the most occurrence of outbreak caused by bacteria either in freshwater or marine aquaculture system. One of the most bacterial disease is caused by *Aeromonas hydrophila. A. hydrophila* become the most prevalent bacteria isolated in diseased fresh-water ornamental fish from an aquarium shop in Kuala Terengganu, Malaysia through bacterial surveillance with Motile

Aeromonas septicaemia becoming the most common disease caused by *A. hydrophila* (MAS) that can affects both freshwater and saltwater fish species. (Anjur et al., 2021). (Lin et al., 2006) also stated that other bacterial pathogens like Streptococcus and Aeromonas have been reported by local veterinarians in Vietnam, but these bacteria have only been isolated from diseased fish on a few occasions. This bacteria produces toxins such as haemolysin and aerolysin which causes haemorrhages, ulcerations, abscesses, ascites, and anaemia as its clinical sign (Anjur et al., 2021)
.

Second most prevalent disease in marine fish aquaculture is streptococcocis caused by bacterium called Streptococcus. *Streptococcus iniae* is associated with sporadic disease outbreaks and can also be carried asymptomatically (Rahmatullah et al., 2017) . Streptococcosis is caused by the bacteria *Streptococcus iniae* and *Lactococcus garvieae*, which are found in marine fish such as olive flounder (*Paralichthys olivaceus*), starry flounder (*Platichthys stellatus*), rain-bow trout (*Oncorhynchus mykiss*), sea bass (*Sebastes ventricosus*), and grey mullet (*Mugil cephalus*) (Choi et al., 2014; Eldar & Ghittino, 1999; Han et al., 2011; Oguro et al., 2014; Woo & Park, 2013). This bacterium usually causes outbreak in country with high temperature and climate. For example , (Zhao et al., 2020) found out that the corresponding mortality rates for zebrafish infected by isolate F3 were higher when the water temperature was 29ºC than when it was 23ºC . This statement also supported by (Rahmatullah et al., 2017) which stated that predisposing factor for the disease during the Streptococcosis outbreak in Terengganu , Malaysia is due to the lake's high water temperature (27.5-31.0°C).

As in Southeast Asia, Indonesian cultured tilapia and Thai cultured tilapia and seabass, mass mortality associated with *S. iniae* infections was recorded (Suanyuk et al. 2010; Anshary et al. 2014; Kayansamruaj et al. 2015). Experimental design done by (Rahmatullah et al., 2017) from tilapia in farmed fish in Kenyir Lake, Terengganu, Malaysia, in 2014 shows that following intraperitoneal exposure to 104, 106, and 108 CFU/ml of the pathogen, the fish showed 90.0 percent, 96.7 percent, and 100.0 percent mortality within 14 days post-infection, respectively with, the majority (60%) of the challenged fish in each group displayed clinical signs such as erratic swimming, lethargy, and inappetence after 6 hours . This result shows that it is true as this disease can also found in Malaysia. Clinical sign associated with this disease includes haemorrhages, opacity of the cornea, spinning near the water's surface, erosion of the caudal fin, and exophthalmos (eye protrusion) are all symptoms. Study by (Li et al., 2021) found out that streptococcal disease symptoms included erratic swimming, appetite, lethargy, uncoordinated movements, and macroscopic lesions such as corneal opacity, exophthalmia, eye haemorrhage, skin darkening, cerebral haemorrhage, splenomegaly, gallbladder filling with bile, and congestion in the inner gill cap two days after the challenge. This disease may cause high mortality rates in marine aquaculture. Every years , streptococcosis flares up in Korea's aquaculture industry, affecting primarily its farmed fish and causing a high level of mortality (Woo et al., 2021). Furthermore , bacterial pathogens *Streptococcus agalactiae* and *Streptococcus iniae* are major tilapia pathogens that can cause high mortality and large economic losses to aquaculture (Qishuo Wang et al., 2020).

Next, most disease in marine aquaculture is caused by *Pseudomonas spp.* During the winter outbreak of 2016 in Egypt , the total prevalence of *Ps. anguiliseptica*, isolated from naturally infected seabream, *Sparus aurata* farms, was 66.08 percent (643/973) (Fadel et al., 2018) . As of 2012, *Pseudomonas baetica* was described as a psychrophile pathogen causing disease in adult cultured wedge sole *(D. cunata*) (López et al., 2017) . (Sun et al., 2020) found out that freshwater cultured fish including ayu (*Plecoglossus altivelis*), rainbow trout (*Oncorhynchus* *mykiss*) and pejerrey (*Odontesthes bonariensis*) and marine cultured fish such as large yellow croaker (*Larimichthys crocea*) and orange-spotted grouper (*Epinephelus coioides*) are example of fish species infected by *P. plecoglossicida* at a high alarming rate. He also added that in addition to having potential economic prospects in agriculture and the environment, *P. plecoglossicida* causes high mortality and significant economic losses in the aquaculture industry. Pseudomonas usually causes outbreak during lower water temperature as immune system of fishes is reduced during this condition. The increased virulence factor at lower temperatures could be due to the fish's immune system being weakened, causing lethargy, inappetence, disorientation, abdominal swelling with severe ascites, and numerous white spots covered on the surface of spleen tissue as its clinical sign , leading to significant financial losses in the aquaculture industry (López et al., 2017). The majority of naturally infected fish by *Pseudomonas anguilliseptica* exhibited spiral-swimming behaviour, abdominal distension, and no visible external lesions (Fadel et al., 2018).

THE EPIDEMIOLOGY OF VIBRIOSIS

Vibriosis is a bacterial infection caused by bacteria from the Vibrionaceae family that affects the entire body. *Vibrio spp.* bacteria characterized by polar flagella enclosed in a sheath and comprised of straight or comma-shaped rods. They are typically pathogens with non-spore forming, oxidase positive and reduce nitrate to nitrite, as well as ferment glycerol, maltose, and fructose. The disease caused by *Vibrio spp.* infection gained widespread attention when it became a threat to farmed fish, particularly in North America, Europe, and Japan. Vibriosis has been affecting various species of economically important cultured marine fishes all over the world for more than a century (Mohamad et al., 2019a) . It is caused by a number of Vibrio species such as *V. harveyi, V. parahaemolyticus, V. alginolyticus, V. anguillarum, V. vulnificus* which is gram-negative bacteria found in marine and estuarine ecosystems, as well as aquaculture farms, making up the major microbiota of these ecosystems.(Soumya Haldar, 2012). Vibrionacae bacteria make up 60% of the heterotrophic bacteria population found in brackish and coastal seawaters. (Zhu et al., 2020) in their experimental result found out *that V. harveyi* is not only the dominant species, but also the most important pathogen in mariculture fish species in China and South Asia. Study done by (Xue et al., 2017) about recirculating aquaculture systems (RASs) in China revealed that *V. harveyi* (18 strains), *V. rotiferianus* (12 strains), and *V. sinaloensis* (12 strains), were identified (15 strains) are the three most common Vibrio species that causes disease in this system .

The occurrence of Vibrio outbreak is strongly related with stress factor which halts the immune system of fish such as sudden changes in temperature. For example, (Albert & Ransangan, 2013) in their study stated that susceptibility of culture marine fish species to vibriosis can be enhanced by water temperature as result shows that fish mortality is higher when the water temperature is high , as well as when there is a high number of Vibrio bacteria present . Additionally, they also found out that the total number of Vibrio was high at high temperatures, which coincided with an increase in disease outbreaks. These findings are consistent with what has been observed by (Eissa et al., 2017) who stated that among naturally infected marine fishes, the highest prevalence was recorded during summer (67.5 %), followed by spring (55 %), then autumn (40 %), whereas the lowest prevalence (27.5 %) was observed during winter. In addition , an increase in seawater temperature from 20 °C to 25 °C resulted in an oyster mortality rate of 77.4% as heat stress increased the abundance of *Vibrio harveyi* and *Vibrio fortis* by 324-fold and 10-fold, respectively, according to qPCR results (Green et al., 2019).

In naturally infected seabass (*D.labrax*), the prevalence of vibrios was 75 percent in the summer, 60% in the spring, 40% in the autumn, and 30% in the winter on an experimental study done using fish from Lake Temsah, Ismailia (Eissa et al., 2017).

Outbreaks of Vibriosis can also been observed in the Southeast Asia region such as in Malaysia, Vietnam and Indonesia. (Albert & Ransangan, 2013) found out that 165 and 78 fish were killed, respectively, by two major outbreaks of vibriosis (April 2010 and September 2010) that occurred at the Sabah aquaculture facility during the study period, and it was clear from the bacterial analysis that Vibrio bacteria were responsible for the outbreaks. A similar results of vibriosis observed in comparative study done by (Kadivar, 2015) in Penang, Malaysia that stated diseased snapper harboured a higher percentage of vibriosis compared to uninfected snapper with the percentage of 74% compared to 62%. Studies of Vibriosis in Vietnam along farmed penaeid shrimp in coastal provinces of the Mekong Delta of Viet Nam such as Soc Trang, Bac Lieu and Ca Mau provinces by (Oanh et al., 2018) revealed that there is outbreak of Vibriosis that causes early mortality syndrome/acute hepatopancreatic necrosis syndrome (EMS/AHPNS). Their experimental result shows from the HP (pale Hepatopancreas) shrimp specimens, 175 Vibrio isolates were isolated, with most of the isolates identified as *Vibrio parahaemolyticus* mainly in areas of intensive and semi-intensive shrimp farming with mortality observed 10 days after stocking. Other studies by (Hisbi et al., 2000) also observed outbreaks of vibriosis in shrimp *Penaeus monodon* larvae in Indonesia with strains were identified as *V. alginolyticus, V. damsela*, and *V. harveyi* as the most prevalent Vibrio species. *V. damsela* tended to be isolated only from post larval stages, while the first two species were typically present throughout the larval phase with a higher prevalence is found during the rainy season than during the dry season in which

Vibrio alginolyticus and *Vibrio harveyi* becoming the dominant species. During the rainy season, they constituted 64.52 % of the bacteria isolated, but only 28.0% during the dry period.

Most cases of vibriosis are associated with skin and muscular lesions in which pathogens are most commonly transmitted through lesions or open cuts in the epidermis (Mohamad et al., 2019a). The skin, gills, and gastrointestinal tract are all points of entry for bacteria, but infection is mostly spread through the fish skin (Frans et al. 2011). (Ina-Salwany et al., 2019) added that ingestion of copepods and chironomids, which are natural reservoirs of *V. cholera* also can result in transmission through oral ingestion. Subsequently , (Soumya Haldar, 2012) believed that fish are usually infected through chemotactic penetration, resulting in the formation of an iron-sequestering system that eventually damages the host due to extracellular products such as haemolysin and she also observed that shrimp are also said to be infected by vibrios in which possible routes of infection through feed, gills, and hepatopancreas. Figure 2 and Figure 3 shows the clinical sign caused by vibriosis.

Figure 2. Swollen and dark skin with ulceration due to vibriosis

Figure 3. Increased corneal opacity

Most of fishes that are affected with these bacteria could shows clinical sign ranging from mild, moderate, and severe such as presence haemorrhage at the spleen, muscle and discolouration at the skin and fins region. Haemorrhagic ulceration on the head with eye opacity and severe haemorrhagic ulceration on the head, ventral surface, and caudal peduncle were found in naturally infected sea bass with *L. anguillarium* and *V. alginolyticus*. Experimental done also revealed that there is presence of darkening at the dorsal surface and severe bilateral exophthalmia in experimentally infected sea bass (control survivors) with post-mortem lesion observed was anorexia prior to death with severe congestion of the internal organs.(Diab et al., 2021) . Figure 4 shows haemorrhage of fish liver due to vibriosis. (Eissa et al., 2017) also found out that haemorrhages were seen on the external body surface of most naturally infected marine fishes, particularly at the caudal fins, ulcerated gill cover, gill erosion and increased corneal opacity with more severe cases causing the appearance of marbling at the congested gills, abdominal distention with presence of fluid and affected liver. Affected fish become lethargic and tend to swim near the surface of the water with abnormal swimming behavior , exophthalmia , corneal opacity and skin ulcer may tends to become hemorrhagic while fin may be necrotized (Ina-Salwany et al., 2019) . Anemia, intestinal necrosis, ascetic fluid, petechial hemorrhages in the muscle layer, liquid in the air bladder are symptoms often exhibited by fish suffering from pathogenic vibrios (Soumya Haldar, 2012).

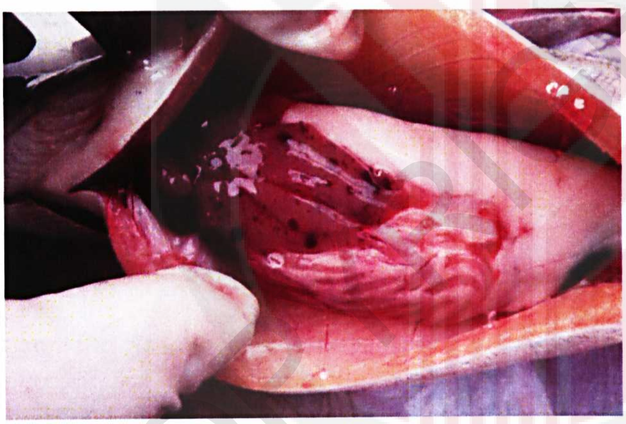

Figure 4. Petechial hemorrhage on fish liver

DISEASE CONTROL AND PREVENTION USING VIBRIO VACCINATION

In the past 50 years, fish have been immunized against a variety of bacterial and viral diseases and are generally considered effective preventative measures. Historically, most licenced fish vaccines were inactivated microorganisms formulated with adjuvants and administered via immersion or injection. Since they mimic the presence of a pathogen naturally and produce strong antibodies, live vaccines are the best option for administering through oral or immersion routes. Subunit or recombinant DNA/RNA particle vaccines are examples of vaccines developed using modern vaccine technology that target specific pathogen components that appear to be more effective in stimulating higher levels of immunity compared to the traditional fish vaccine (Ma et al., 2019).

Aquaculture has made good progress in recent years, however, there remain many cases of infectious diseases that result in the death of about 10% of cultured aquatic animals worldwide annually. There, a variety of fish vaccine has been developed to prevent further effect caused by fish disease. Fish vaccine development has made significant progress over the last four decades, with 24 licenced fish vaccines now commercially available for use in a variety of fish species. Whole killed, peptide subunit, recombinant protein, DNA, and live attenuated vaccines are among them (Adams, 2019). (Qingchao Wang et al., 2020) stated that vaccines are unquestionably the most appropriate and focused method for controlling various types of fish diseases from the standpoints of efficiency, safety, the environment, and ethics as researchers in China have put in a lot of effort into fish vaccines, six domestic and one imported aquatic vaccine products have received the national veterinary medicine certificate so far. For example, different types of vaccine produced by China, which is vaccines against grass carp haemorrhagic disease, inactivated vaccine against *A. hydrophila* sepsis, live vaccine against *E. tarda*, anti-idiotypic antibody vaccine against *V. alginolyticus*, *V. parahaemolyticus*, and *E. tarda* and live vaccine against *V. anguillarum*.

In marine fish, disease associated with *Vibrio spp.* had been widely observed in different region such as in Southeast Asia or western countries. As a matter of fact, the development of a Vibrios vaccine is strongly recommended to control and prevent outbreaks of this disease.

Clinical sign associated with this disease includes lethargic, abnormal swimming behaviour, haemorrhagic skin ulcer, fin erosion and exophthalmia with increase corneal opacity (Mohamad et al., 2019b). However , vibrio-associated clinical signs in fish can be reduced by vaccination as this is proved by (Liu et al., 2018) from their experiment that claimed that most of the vaccinated fish demonstrated no clinical symptoms, but a number of control fish exhibited severe symptoms of liver and spleen swellings, blackened bodies, petechial haemorrhage, and erratic swimming patterns. However, if left untreated, high fish mortality could be observed.

Thus, various vaccines are used to prevent or reduce the clinical signs and mortality rate associated with this disease. For instance, the immunization with either Vibrio parahaemolyticus ghost vaccine (VPG) or Recombinant Vibrio parahaemolyticus ghost vaccine (rVPG) resulted in increased survival against infection at 80% relative percentage survival rate (RPS) by either V. parahaemolyticus or V. alginolyticus, with rVPG proving to be more effective where rVPG works by increasing the expression of tnf, il1, il6, il8, and il10, as well as c3b, lyz, and tlr5, the key players linking the innate and adaptive immune responses in response to microbial stimulation, hence providing stronger innate immune responses (Ji et al., 2020). At 4th week post vaccination , fish immunized with monovalent vaccines (of either *V. alginolyticus* bacterin or *V. parahaemolyticus* serotype O11:K40 bacterin) had the highest antibody levels against each specific antigen, indicating the presence of immunity created through vaccination (Aly et al., 2021).

In other studies, vaccine against *Vibrio anguillarum* provides promising result to increase survival rate of fish infected by this disease. For example, experimental design done by (Liu et al., 2018) observed after Tiger puffer (*Takifugu rubripes*) being challenged with *V. anguillarum* MVM425 on day 28, vaccinated juvenile and adult fish had survival rates of 92.22% and 85.56%, respectively, whereas the control group had survival rates of only 16.67% and 26.67%. As a result, they conclude that vaccinated juveniles and adults have a higher relative percentage survival (RPS) against V. anguillarum, with RPS of 90.67% and 80.31%, respectively. These result are supported by (Zhang et al., 2021) that found out that after challenge with V. anguillarum, low, medium, and high doses of inactivated bivalent vaccine (named IVVah1) showed higher survival rates of 56.80%, 86.67%, and 90.0%, respectively compared to the unvaccinated control group which shows high mortality rates of 96.67% and 91.33% after challenged with *V. anguillarum* and *V. Harveyi* at 15 days post infection. Other studies by (Kwon & Kang, 2016) using subunit vaccine (recombinant flagellin-A [rFlaA]) and immunostimulant (CpG-ODN 1668) against *Vibrio anguillarum* in tilapia produced the best result that shows subunit vaccine group without use of CpG adjuvant (FlaA-only) and the group treated with immunization subunit vaccine rFlaA followed by CpG as an adjuvant (rFlaA-CpG) had significantly higher survival rates (65–77% and 40%, respectively) compared to the control group which have higher cumulative mortality rates of 100%.

Researchers, on the other hand, have tested vaccines against a variety of Vibrio species, including *Vibro harveyi*, which has a high prevalence in marine aquaculture. It has been found that Vibrio harveyi is a gram-negative bacterium that inhabits mostly aquatic environments as well as marine ones, and it can also infect many aquaculture animals (H. Wang et al., 2017). The use of vaccine in fish has been highly suggested by (Nguyen et al., 2017) on their experimental procedure that suggested *V. harveyi* inactivated vaccine along with ISA763 AVG metabolized adjuvants triggered grouper immune responses, elevated antibody titers, displayed strong antibacterial effects following challenge and provided good protection while enabling a simple, high-efficiency, cost-effective, and low-stress prevention of *V. harveyi* infection by orange-spotted groupers with a single injection. Resulted obtained from their experiment stated that at

6 and 12 weeks after vaccination, the grouper was highly protected against a homologous *V. harveyi* strain challenge, with relative percentage survival values of 100% and 91.7%, respectively while 80.6% mortality rate at 6 weeks post injection (PI) and 47.2% mortality rates at 12 weeks observed in the control group (unvaccinated group). Table 2 stated the mortality rate and relative percentage survival (RPS) of vaccinated and unvaccinated group. This is also supported by (H. Wang et al., 2017) that studied glutathione peroxidase (GPx) DNA vaccine against *Vibrio harveyi* in orange-spotted grouper (*Epinephelus coioides*). Higher specific antibody titers being observed in the serum of immunized groupers compared to control group as fishes infected in control group started to show mortality on the second day post infection and increasing rapidly through the subsequent days. However, high RPS (77.5%) was obtained when fish immunized with DNA vaccine like the subunit vaccine indicating the efficacy of the glutathione peroxidase (GPx) DNA vaccine to prevent further outbreak of Vibriosis.

Therefore, vaccine outperforms the competition in terms of efficacy, safety, and ease of use. It also has greater economic benefits, making it the best method for controlling fish diseases. Vaccination is not only cost-effective and simple, but it can also trigger a powerful immune response. In addition, usage of vaccines is safer and more effective way to prevent and control vibriosis in aquaculture than antibiotics and other chemotherapeutics.

Groups	Challenge replicates	No. of fish death	Mortality	RPS (%)	Average RPS (%)
Challenge at 6 weeks post infection					
Control	1	15/18	83.3	0	0
	2	14/18	77.8	0	
Vaccination	1	1/18	5.6	93.3	85
	2	2/18	11.1	85.7	
Challenge at 12 weeks post infection					
Control	1	8/18	44.4	0	0
	2	9/18	50.0	0	
Vaccination	1	0/18	0.0	100	94.4
	2	1/18	5.6	88.8	

Table 2. Mortality rate and relative percentage survival (RPS) of vaccinated and unvaccinated group.

THE COST OF DISEASE

Diseases in the ocean are an inevitability, and they have important economic impacts for fisheries and aquaculture. Diseases and epizootics have caused damage on the fast-growing aquaculture industry as well as natural aquatic populations in the wild over the years. In two ways, marine diseases can affect the economic value of a species which is consequence from decreased in catch due to decreased biological productivity, whether it is result of higher mortality, slower growth or immune defences provided by hosts and subsequent host responses to infection that are damaging to hosts and to infectious agents. Second, it is typically associated with bad tastes or appearances or with risks to human health (Lafferty et al., 2015)

Study by (Peterman & Posadas, 2019) about different fish disease such as *Aeromonas hydrophila, Flavobacterium columnare* and *Edwardsiella ictaluri* observed a great economical loss. For example, (Lafferty et al., 2015) stated that it was calculated that disease-related losses of catfish sales were worth $10 million (RM41.81) million at farm-gate value. Medicated feed ($1.9 million) (RM7.94 million), chemical applications ($0.6 million) (RM2.51 million), and miscellaneous ($0.1 million) (RM0.42 million) constitute most of the lost income due to increasing disease management and control costs and therefore $16.9 million (RM70.67 million) been calculated as total expenses due to disease outbreaks. Table 3 stated the direct economic loss due to disease outbreak at east Mississippi during 2016. Table 4 explained economic impact of Vibrio related disease in aquaculture system.

Loss or expenditure	Amount ($ millions of dollars) (RM)
Foregone sales	
Fish loss	$10.0 (RM41.82)
Production loss	$4.3 ((RM17.98)
Total foregone sales	$14.3 ((RM59.80)
Forgone income	
Medicated feed expenditures	$1.9 ((RM7.95)
Chemical expenditures	$0.6 ((RM2.51)
Other's expenditures	$0.1 ((RM0.42)
Total foregone income	$2.6 ((RM10.87)
Direct economic loss (Total foregone sales + total foregone income)	$16.9 ((RM70.68)

Table 3. Economic loss due to disease outbreak at east Mississippi during 2016

Country	Vibrio spp. Caused disease	Losses and other impacts	Reference
Ismailia	*V. anguillarum* *V. parahemolyticus*	Infected fish displayed skin ulcers on the ocular side and a reddened abdomen with scattered splotches of haemorrhaging, along with fin erosion	(Eissa et al., 2017)

Australia	*V.harveyi* *V. fortis*	*C gigas* suffered a mass mortality rate at high temperature (25°C), mortality began on day 2 and continued to day 6 post infection	(Green et al., 2019)
China	*V.harveyi*	Severe fin necrosis, eye muddying and proptosis, and subcutaneous haemorrhage in experimented fishes	(Zhu et al., 2020)
Malaysia	*V.harveyi*	A high mortality rate observed in April and September 2010 when temperatures were higher (32°C)	(Albert & Ransangan, 2013)
Egypt	*V.anguillarum V. parahemolyticus*	*Sparus aurata* suspected with *Vibrio spp.* displayed haemorrhage on body surface, corneal opacity and congested liver and kidney	(Hassan et al., 2021)
Viet Nam	*V. parahaemolyticus*	pale hepatopancreas, gut with discontinuous contents and high mortality in shrimp	(Oanh et al., 2018)

Table 4. Economic impact of Vibrio related disease in aquaculture system

(Tavares-Dias & Martins, 2017) also stated due to several factors in the production system, disease outbreaks in finfish are common, resulting in heavy infections and high fish mortality. Accordingly, losses due to infectious diseases and parasites have been calculated based on the assumption that fish mortality will amount to 15 % of total production ((i.e., fingerlings purchase cost, equipment, feed and feed additives, mortality, and growth loss), with the overall production costs per fish over US$ 0.28(RM1.17). According to estimates, the disease-caused loss on freshwater fish farms in Brazil amounts to about US$84 million (RM351.37 million) through both direct and indirect losses from diseases in farmed fish (Tavares-Dias & Martins, 2017). Another studies by (Subasinghe et al., 1998) stated estimates indicate that disease and environmental issues in Asian countries have probably led to annual losses in the aquaculture sector of in excess of US$ 3.0 billion (RM12.55 billion) per year while a viral outbreak in 1993 had a detrimental effect on shrimp production in Ecuador. High mortality rate could be observed in outbreak of disease in marine aquaculture. (Publication, 2014) observed the percentages of liveability showed considerable difference across fish species in Egypt and causes of mortality, ranging from 70% for Carp species exposed to Mycotoxins to 93.50 percent for Mugil Capito in control group. They also found out that motile *Aeromonas septicaemia* was the most common disease impacting Egyptian fish farms, reducing net profit by 103.95 LE (RM27.70), 173.95 LE (RM46.36), and 83.31 LE(RM22.20) /100 fish for the fish *Oreochromis niloticus*, Common Carp, *Mugil Cephalus*, and *Mugil Capito*, respectively. Studies by (. et al., 2004) in Bangladesh stated that disease caused significant financial losses to farmers, totalling Tk.20.651(RM1006.44)/ha per year with the average loss of Tk.26817(RM1309.23)/ha/year.

THE COST AND BENEFIT OF CHANGE IN AQUACULTURE HEALTH MANAGEMENT

Partially budgeting is a financial method of assessing the costs and benefits of individual changes in a business unit which each component identifies two changes in operation that will increase profits, while the other two component identify changes that will decrease profits (Hanson et al., 2007; Stockton, 2010). Element that makes up partial budget including added income, added costs, reduced cost and reduced income. If a new business is to be added, added income is usually used to make an estimate based on realistic yields, product quality, and prices. When changes are supposed to improve financial performance, overestimation could lead to inaccurate decisions and lower financial performance (Tigner, 2018). Added cost on the other hands will be the costs associated with the development or use of a new product or process. Non-cash costs such as labor and depreciation may also be included on added cost. Thirdly, reduced cost refers to the costs incurred for abandoning the current practice or commodity for the new one such as, custom work, repairs, veterinary expense, interest expense and paid labor. Lastly, reduced income refers to the return given up because there are no longer producing the commodity constructed or practice currently used (Budgeting, n.d.) (Hanson et al., 2007) stated that a partial budget examines how a change in the operation will affect the operation's profitability once it has been fully implemented with several steps to be taken to obtain the result from identifying changes that brings any benefits to the operation , identifying changes that reduces profits gained to the last step which is identifying changes that would result to increase cost of production.

One type of partial budget model is stochastic partial budget in which based on this type, there are presence of many probabilities created ranging from the lowest probability to the highest probability rather than proceeding with only one confirmatory result. Several step have to be taken in order to apply this type of partial budget on certain condition such as identifying the proposed changes, listing the key information necessary for analysis and identifying the positive and negative effects of uncertainty such as in production , price, cost and information (Stockton, 2010). (Stockton, 2010) also added that in term of monetary for their cost or benefit, stochastic partial budget specifies the measurement in the form of a range rather than determining the highest to the lowest outcome

The usage of partial budget in every economic sector helps in determining the best choice in minimizing a great economical loss due to many factors such as reduced in production rate, reduced exports and disease in animal or farm-based culture. In animal farming, partial budget has been widely used to help farmer to make the best choice to maximize their production with minimum production cost. Through the financial evaluation of disease control measures, such as vaccination, farmers can weigh the losses against the costs of an intervention (Delphino et al., 2019). In marine aquaculture, this type of model being used to control loss of profit due to disease either through prevention such as vaccination, culling the entire population to prevent disease from spreading aggressively, changes in feeding system or using different system to maximize production. Studies by (Brennan et al., 2000) stated that investment on higher quality and price of feed lead to increase profit made in shrimp aquaculture . In the study, it stated that investment of higher quality and prier feed contributes to increased profit in shrimp aquaculture. In the study, extra profit gained when using higher price food which is Grade A $0.96 per kilo (RM4.01 per kilo) compared to lower quality food which is Grade B feed $0.72 per kilo (RM3.01 per kilo), and Grade C feed ($0.48 per kilo (RM2.01 per kilo) as extra revenue can be made as much as is $1.10 per kilo (RM4.60 per kilo) of feed although the difference in price between these two feeds is only $0.24 (RM1.00). Hence, they concluded that utilizing the highest-productivity feed would seem to yield extra productivity. In addition, partial budget help to determine which type of farming system could yield the highest profit and production. Changes of production system experimented by (Daud Om et al., 2020) help farmer to improves survival rates of fish in different farming system used which is named recirculating aquaculture system (RAS) . This is true as finding from this experiment observed that recirculating aquaculture system (CENTS-RAS 2.0) produces 70 kg /m3 of biomass production, higher than the of conventional method (CENTS-FT) which yield only 18.75 kg /m3 other than maintaining higher survival rate in hybrid grouper fish which is 90%. They also observed after a 50-day care period using this type of system, the 20,000 seeds of initial size 5.0 cm (initial price is RM3.12) can produce more than RM70,100 in net revenue, concluding that recirculating aquaculture system (CENTS-RAS 2.0) increases farmer incomes and reduce seed imports from abroad.

The decision made in culling animals due to disease outbreak if most crucial aspect to control disease. However, partial budget could also use to calculate either culling or treatment if the best cost-effective ways to minimize loss. This concept being used in study by (Brun et al., 2003) to control cardiomyopathy syndrome in farmed Atlantic salmon *Salmo salar* in Norwegian aquaculture. In this study, they stated that it is more cost-effective to cull fish at early disease outbreak rather than giving treatment. For example, direct loss due to the disease is NOK 33.5 (RM16.29) to 66.3 million (RM32.24 million) if CMS is experienced by 14% of all groups in the target population. However, by applying budget model, early culling in order to prevent further loss have helped the farmer a lot as slaughter of ten or fifteen percent of the fish, over a period of four months, increases the average group loss to approximately 0.9 million NOK (RM0.44 million) and 1.4 (1.3 to 1.6 within 90%) which result in the point at which a farm is no longer losing or reduced loss of money when slaughtering 2 to 3 months before actual harvesting. This statement also supported by (Pettersen et al., 2016) which stated harvesting infected farms prior to outbreaks reduces the disease spread to neighboring farms, thereby breaking the path of transmission and reducing the virus reservoir in cases of viruses outbreak and implementing harvesting strategies triggered by disease can be a cost-effective tool to combat pancreas disease virus(PD).

It was also found that strategies that involved early harvest interventions and where farms were harvested at losses to provide economic benefits for a group of producers were the most effective in reducing infection pressure and providing economic benefits (Pettersen et al., 2016). In the other hand, study by (Moran & Fofana, 2007) explains about investment on disease control against 3 types of fish disease named infectious salmon anemia (ISA), viral hemorrhagic septicemia (VHS) and infectious hemorrhagic necrosis (IHN) to increase profitability. They observed that in terms of return on investment, infectious salmon anemia (ISA) and viral hemorrhagic septicemia (VHS) surveillance and control programs seems to be providing acceptable returns on public funds invested. Assuming infectious salmon anemia (ISA) for example, each £1(RM5.68) invested will earn £3.2(RM18.18), £3.6(RM20.45), and £4.3(RM24.42) in different scenarios which is in 6 months (LRO), 12 months (MRO) and 18 months (HRO) post outbreak and the return on investment for viral hemorrhagic septicemia (VHS) was £5.7(RM32.38), £5.8(32.94), and £6.8(RM38.62) for every £1(RM5.68) invested in scenarios LRO, MRO and HRO.

On other studies, partial budget had been used to determine the effect of disease to fish production based on the size of the farm and weigh of fish to be sold in the market. This study was done by (Fernández-sánchez et al., 2021) by implementing 3 different strategy of fish farming with production of seabass of 450 grams with a sales price of 5.80 € (RM28.06)/kg as strategy 1 with 90% survival rate , 1 kilogram with sales price of 8.72 € (RM42.18)/kg and 85% survival rate and finally , 2 kilogram of seabass priced at 11.46 € (RM55.44)/kg. Their result stated that even though producers obtain positive net operating profits, these are decreasing as the biomass produced (farm size) and the size of the fish produced (production strategy) are decreasing. Higher average operating cost needed to control disease in small-sized farm which is 5.72 € (RM27.67)/kg compared to small-sized farm at 4.43 € (RM21.43)/kg and medium-large-sized farm at 3.83 € (RM18.53)/kg when strategy 1(450-g fish) is used. Therefore, a small-sized farm's average net operating profit is 1.37 € (RM6.63)/kg for strategy 1 (450 g of fish), 4.48 € (RM21.67)/kg for strategy 2 (1 kg of fish), and 7.05 € (RM34.10)/kg for strategy 3 (2 kg of fish). Hence, they concluded that average operating cost in (medium-large farm with production strategy 1) is lower which is about 2.41 € (RM11.66)/kg compared to small farm using strategy 3 costing about 8.07 € (RM39.04)/kg for viral encephalopathy and retinopathy (VER) disease while 0.40 € (RM1.93)/kg average operating cost in medium-large farm with production strategy 1 than 1.42 € (RM6.87)/kg in small-sized farm.

Usually, outbreak of disease caused increase of market price of animals being sold. This is supported by (Moran & Fofana, 2007) which found out that an outbreak of a disease will cause shortages in the industry, depopulation, and movement restrictions, which will lead to higher prices. However, using partial budget model, this can be prevented and improved such as the usage of vaccination to treat fish disease. For example, vaccination program against *Streptococcus algagactiae* would likely be worthwhile in Nile tilapia farms experiencing streptococosis with positive net return (benefits>cost of production) as 20% mortality rate being observed in 97.9% interaction and high relative percentage survival of 50% and also observed numbers of fishes are more likely to survive after vaccination, stating additional benefit of vaccination (Delphino et al., 2019). A baseline partial budget model is shown for one production cycle starting with 20,000 fingerlings, 20% mortality over the entire production period, a 5% improvement in FCR, and a 60% return on investment for vaccines against S agalactiae on Table 5.

Cost	**No**	**Cost/Unit US/$(RM)**	**Total US/$(RM)**
New cost			
Vaccine dose	20000	US/$0.03(RM0.13)	US/$635.84(RM2658.13)
Vaccine labor	20000	US/$0.01(RM0.042)	US/$289.02(RM1208.25)
Antibiotic	70	US/$0.003(RM0.013)	US/$20.23(RM 84.57)
Fixed consumption	1069	US/$0.72(RM3.01)	US/$772.25(RM3228.39)
Revenue foregone			
Total cost			**US/$1714.34(RM 7166.80)**

Cost	**No**	**Cost/Unit US/$(RM)**	**Total US/$(RM)**
Cost saved			
Reduction in antibiotic usage	4500	US/$0.003(RM 0.013)	US/$130.06(RM543.39)
New revenue			

Extra fish sales	2040	US/$1.50(RM 6.27)	US/$3065.90(RM12809.33)
Total benefits			**US/$3195.95(RM13352.68)**
Change in income due to vaccination			US/$1478.61(RM6177.63)
Change in income per fingerlings			US/$0.07(RM0.29)

Table 5. Partial budget for vaccination against S. agalactiae

Application of vaccine in fish farming is also supported by (Thorarinsson & Powell, 2006) in their experimental study that found out vaccine against bacterial diseases in fish typically reduces antibiotic dependency compared to fish without the vaccine. As a result, from the perspective of the salmon producer, lowered production costs and more profitable operations achieved resulting from vaccination regardless of the disease risk or market price and concluded that fish farmers can improve efficiency and profit by investing in aquaculture vaccines. This is also supported by (Jillian et al., 2001) on their experiment of vaccine application in channel catfish production in USA that resulted in greater total additional benefits compared to total additional cost, producing a net benefit of $1,443 (RM6036.79)/ha to the producer. It was estimated that using vaccinated fingerlings in channel catfish production would result in an additional $1,590 (RM6651.76)/ha in revenue due to the harvest of more biomass and lower feed costs. Finally, they observed that vaccinated fish were significantly heavier at harvest (357.5 ± 30g) than controls (289.5 ± 20g) and the feed conversion ratio (FCR) of vaccinated fish was significantly higher compared to unvaccinated fish (1.35 vs. 2.13).

PARTIAL BUDGET FRAMEWORK TO SUPPORT VACCINATION IN AQUACULTURE FARMS IN MALAYSIA

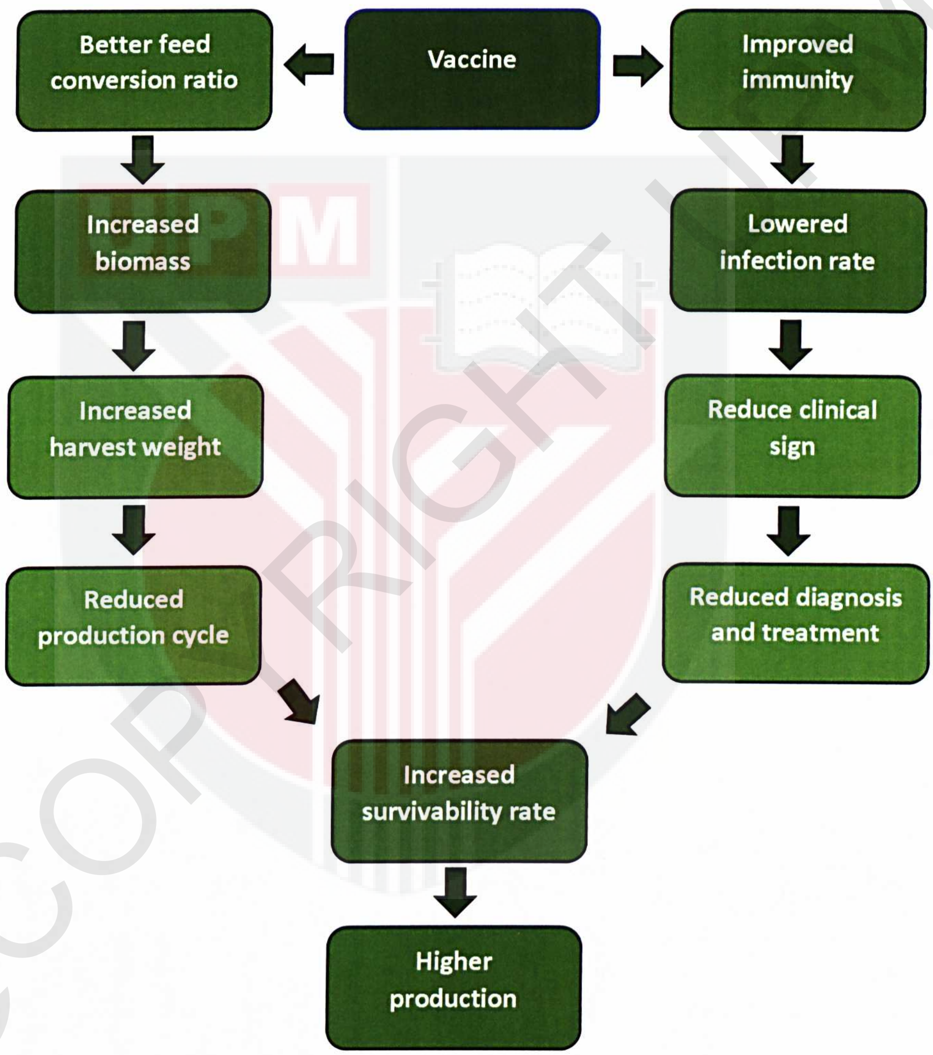

Figure 5. Biological impact of fish vaccination.

TABLE 6; PARTIAL BUDGET MODEL OF FISH VACCINATION

Benefits	Costs
A. Additional income • Increase feed conversion ratio • Increase harvest weight • Reduces mortality rate • Higher production • Increase market price • Increase profit	**Additional Cost** • Vaccine application (per fish) • Labor cost
B. Reduced cost • Cost of other treatments (antibiotic) • Reduces dx and treatment • Reduce production cycle	**E. Reduced income** • None
C. Total benefit (A+B)	**F. Total cost (D+E)**
Net change in profit (C – F)	

Table 6. Partial budget model of fish vaccination

Application of vaccine helps in increasing immunity of fishes hence reduces the probability of disease outbreak (Figure 5). Vaccinated fish tends to develop immunity and resistant to disease outbreak. This is proven by many experiments done by researchers which majority observed a high survival rate and low mortality route in vaccinated fish group compared to the unvaccinated control group. For example, majority of the vaccinated fish group in experimental done by different researchers obtains a higher relative survival percentage up to >70%. Furthermore, clinical signs and mortality rates can be reduced by using vaccine as it is proven that application of vaccine stimulates antibody production in fishes which consequently providing a better immune response towards disease. Thus, the usage of other treatment or medication such as antibiotic could also reduce as antibiotic tends to cause several impacts such as reduced production, increases resistance over time, causes risk to consumers, production of low-quality fishes and ineffective against viral disease. Among the additional revenue benefits is an increase in feed conversion ratio, which leads to increased fish weight at harvest. Consequently, higher fish production can be achieved as well as the weight gain during harvest. This in turn will increases the market price of the fishes sold, resulting in increased profit made by the farmers. As a result of fish vaccine implementation, additional costs are required for the operation which includes amount of vaccine needed with different prices range, labor, and equipment cost. Therefore, partial budget model is used to determine if vaccination or other treatment cost is beneficial in prevention disease outbreaks in caged marine fish production. Although partial budget has been widely used in farmed industry, there is still lacking specific data or information on cost-benefit of fish vaccine in caged marine aquaculture.

Conclusion

As a result, we can observe that the benefit outweighs cost of production in vaccinated marine fish farm. For example, vaccination provides an additional income to the farmers if vaccination is implemented. This can be seen with vaccinated fish shows a greater immune response hence reducing infection rates and clinical sign. Vaccinated fish have a better feed conversion ratio which in turn increase its biomass, leading to increase weight at harvest. Operational costs include extra vaccines, labor, and equipment costs which is lesser compared to loss due to fish death because of not vaccinating the fishes. Therefore, partial budget can be helpful in making decision on fish vaccination for vibriosis as there are more benefits can be gained compared to economical loss due to fish death.

Recommendation

For further studies, we highly recommended to find papers that are strongly related with partial budget vaccination in fishes as most of the papers found is extracted is not specifically on fish vaccination.

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